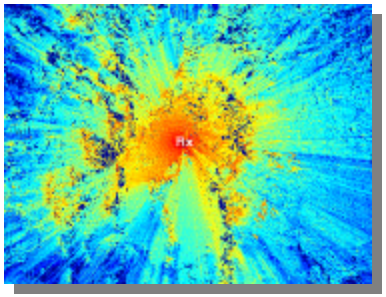
KASSPER

KNOWLEDGE-AIDED SENSOR SIGNAL PROCESSING & EXPERT REASONING



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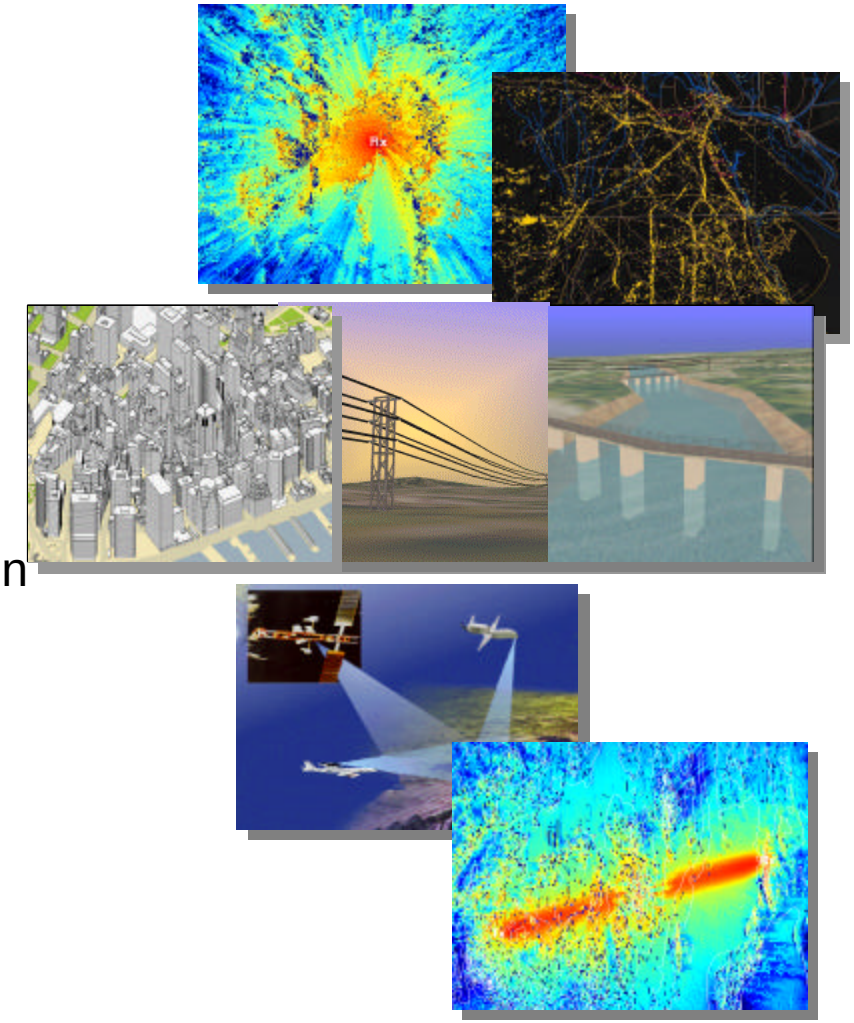
First Annual KASSPER Workshop
April 3, 2002
Capitol Hilton
3701 N. Fairfax Drive
Washington, D. C. 22201

When is There a Problem?

Extremely suboptimal radar performance can occur if one or more of the following occurs:
(High false alarm rates and/or low P_d)

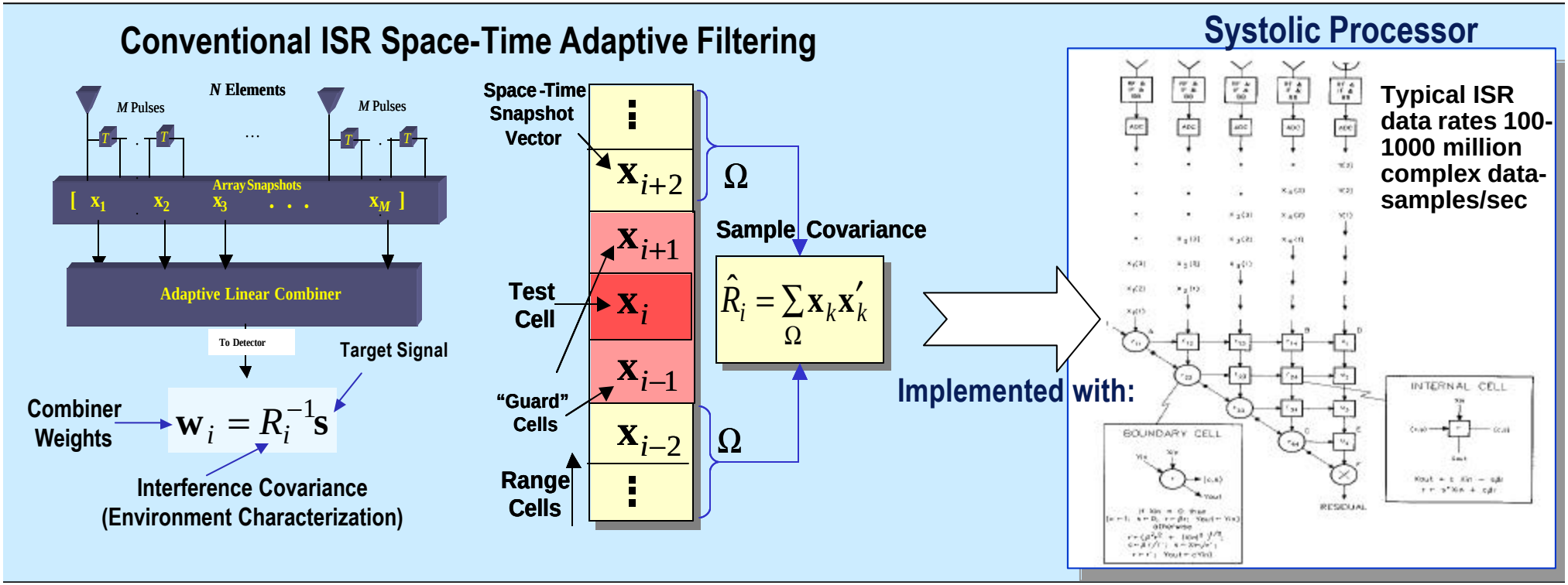
- Heterogeneous Clutter
  - Rapidly varying terrain
    - Mountainous (rapid elevation/reflectivity variation)
    - Rapid land cover variations (e.g., littoral)
- Dense "Target" Backgrounds
  - "Moving Clutter"
    - Military/civilian vehicles
- Large Discretes and "Spiky" Clutter
  - Urban clutter
  - Power lines, towers, steep mountainous terrain
- Range-Varying (Nonstationary) Clutter Loci
  - Bi/Multistatics
  - Nonlinear array geometries (e.g., circular arrays)
- Joint "Hot and Cold Clutter" Problem
  - Multipath terrain scattered interference



One or More of the Above is Almost Always Present in Real-World Ops!

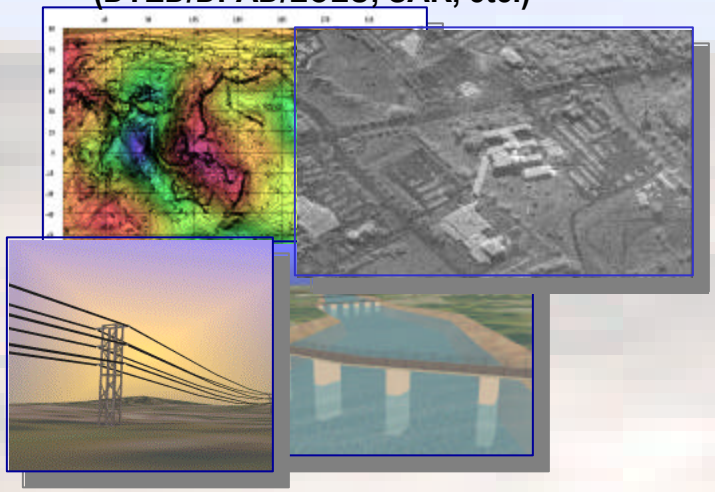
What are the Problems?

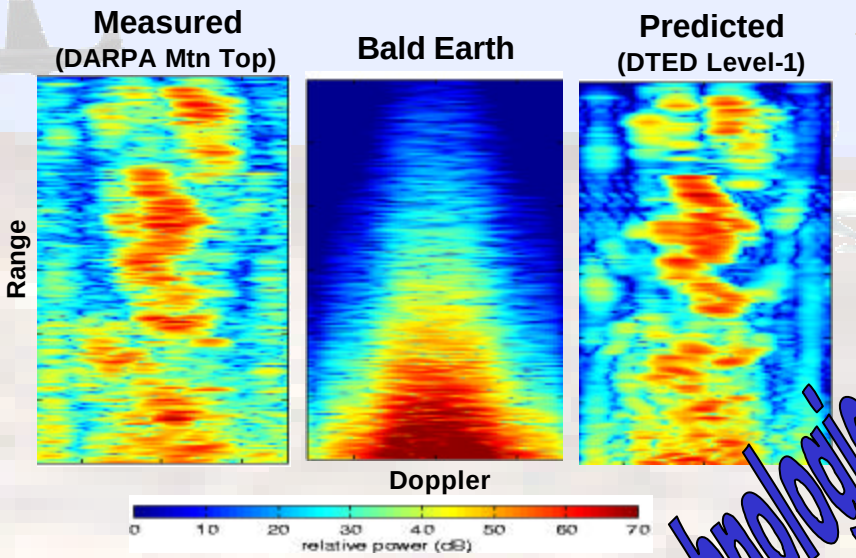
- Current systems implement highly restrictive adaptation techniques
  - Require environment to remain “stationary” and “homogeneous” during “adaptation” (e.g., CACFAR, STAP)
  - Significant performance degradation in “complex” interference environments
- Only suboptimal piecemeal “patches” to problem have been considered
  - No potential solutions exist that comprehensively address the totality of issues
- Fundamental shift in the basis for adaptation required



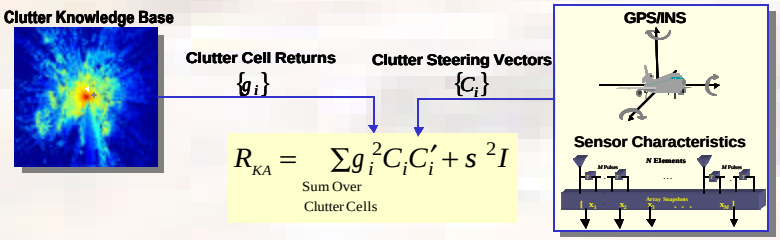
KASSPER Enabled by a Confluence of Emerging Technologies

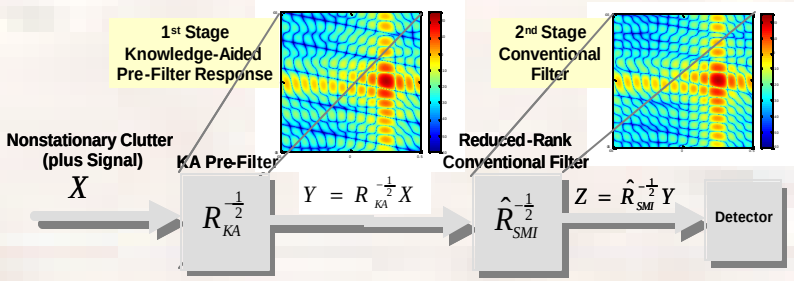
Radar Environmental Knowledge Bases (DTED/DFAD/LCLU, SAR, etc.)



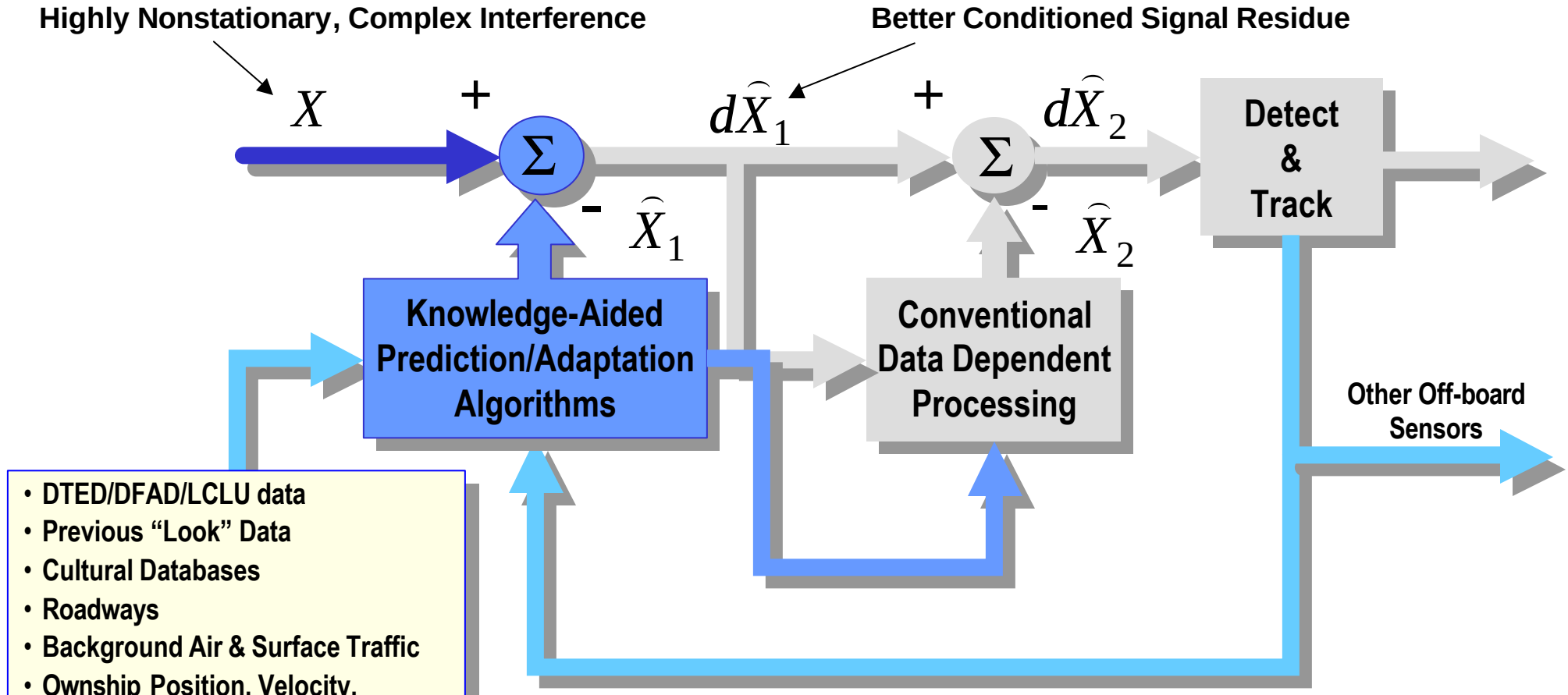


KASSPER





High-Level KASSPER Processing Chain



- DTED/DFAD/LCLU data
- Previous "Look" Data
- Cultural Databases
- Roadways
- Background Air & Surface Traffic
- Ownship Position, Velocity, Orientation
- System Calibration Information
- EMI Data
- Other

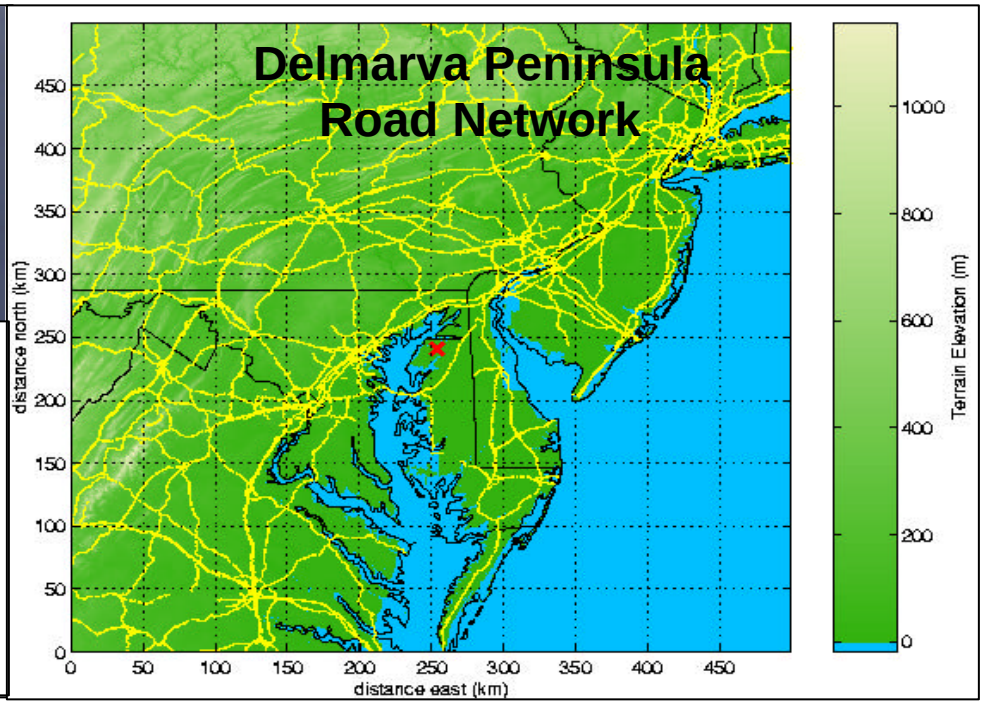
- KASSPER will:
  - Develop next generation intelligent signal processing algorithms
  - New HPEC architecture for real-time ISR
  - Real-time flight demos

Flight Tests Conducted Over Populated Regions

- Nature of program allowed for flight tests in "real-world" environments!

- **L-band transmit frequency**
- **20kW peak transmit power**
- **Variable PRF**
  - **500 Hz, 2kHz, 7kHz**
- **LFM or gated-RF**
- **0.8 microsecond range resolution**
  - **120 m**
- **Typical compression ratio of 63**
- **0.8 MHz receiver bandwidth**
- **7.5 degree Tx beam or "blob" (3x) pattern for broad coverage**

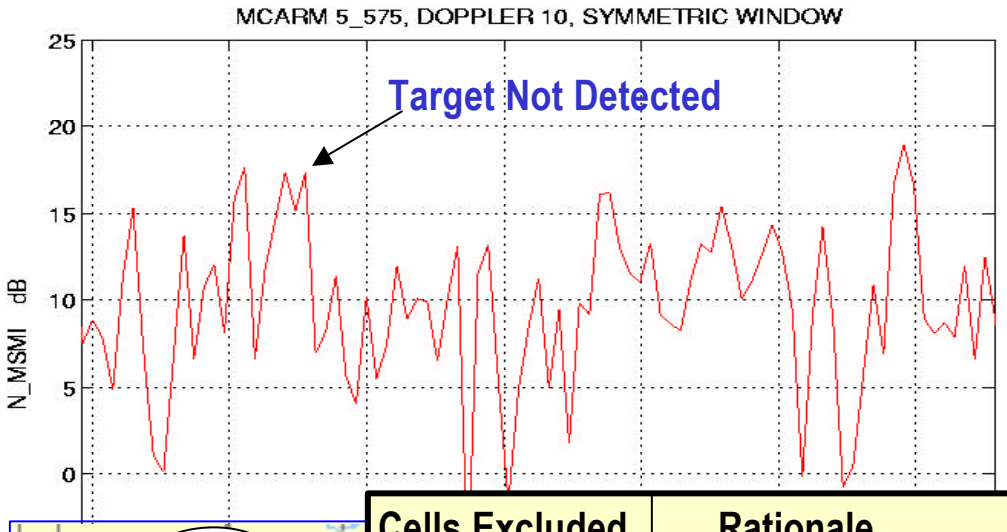
1.25 MHz IF center frequency
5 MHz IF sampling rate
For digital IQ
Test manifold for channel balancing
Tone injected for channel EQ
Range measured steering vectors
32 sub-arrays
24 Receivers
Sum, Difference
11 over 11 half-wavelength
128 radiating elements total (32x4)



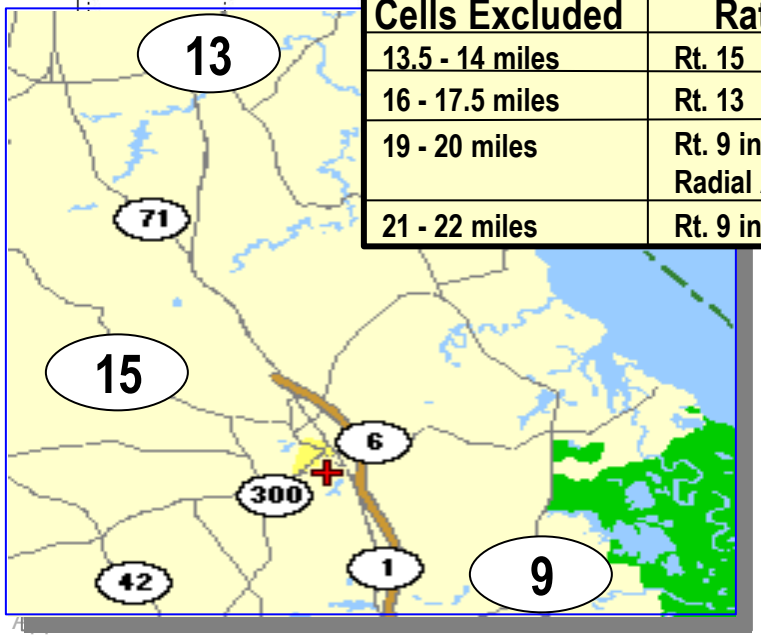
MCARM platform located east of Baltimore heading south, height = 10km
Yellow dots show discretes (urban clutter) and road network

KASSPER Dramatically Improves P_D and SINR in Airborne Radar Flight Test

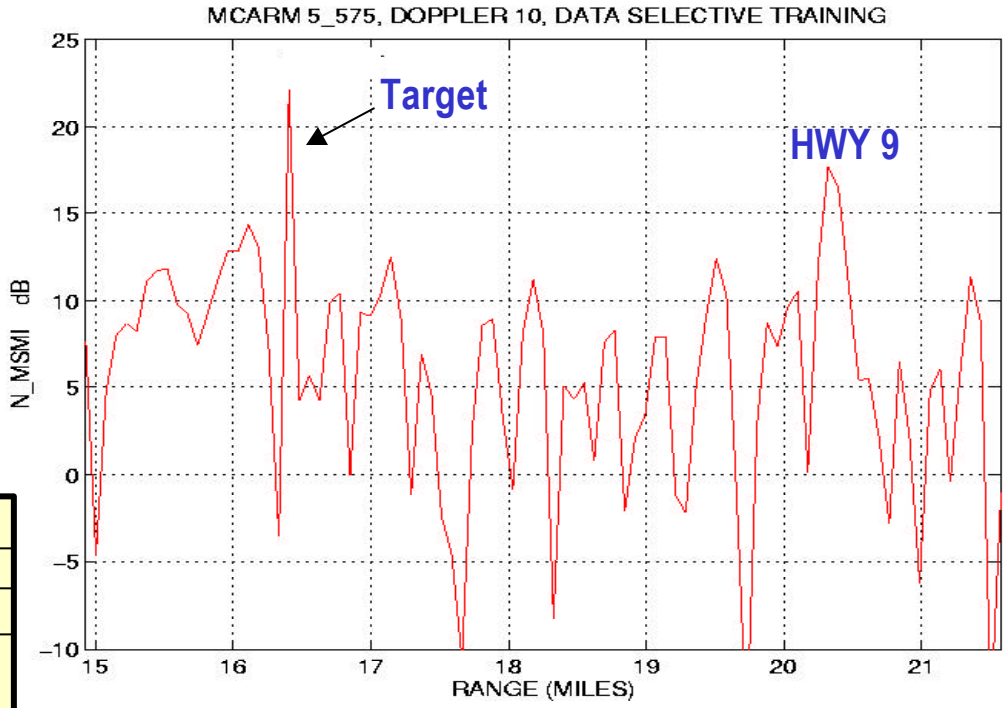
Sliding Window: 2xDoF with 4 guard cells

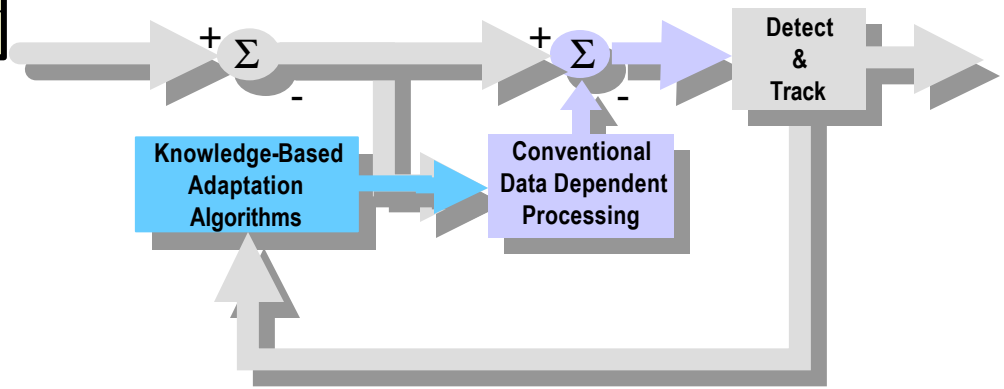


Cells Excluded	Rationale
13.5 - 14 miles	Rt. 15
16 - 17.5 miles	Rt. 13
19 - 20 miles	Rt. 9 in Sidelobe Region, Radial Alignment
21 - 22 miles	Rt. 9 in Mainlobe



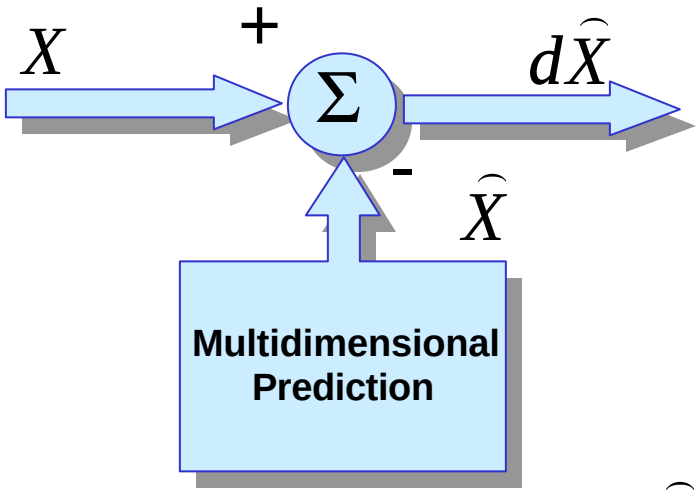
Knowledge-Based Training

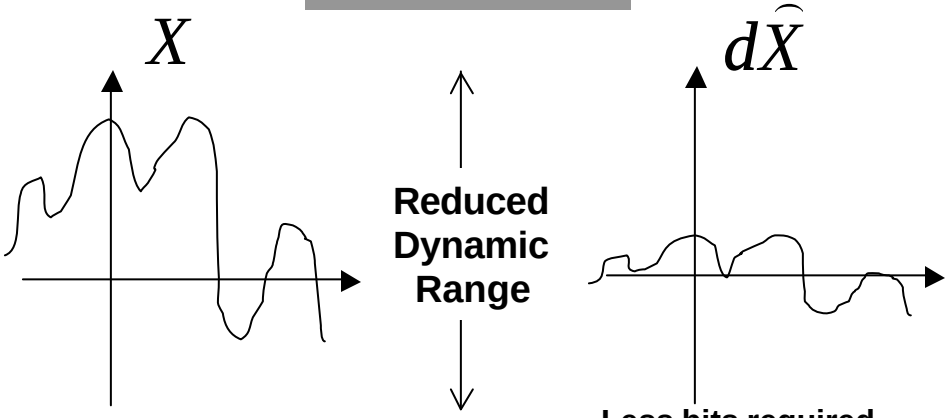




Information-Theoretic Interpretation

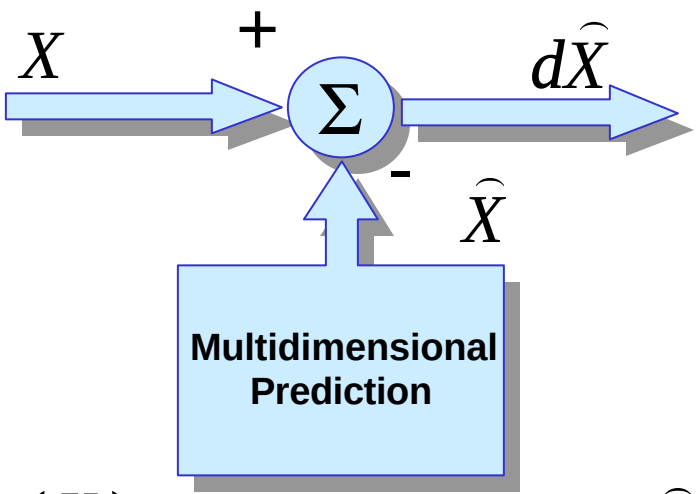
Bit Reduction (Predictive Coding)

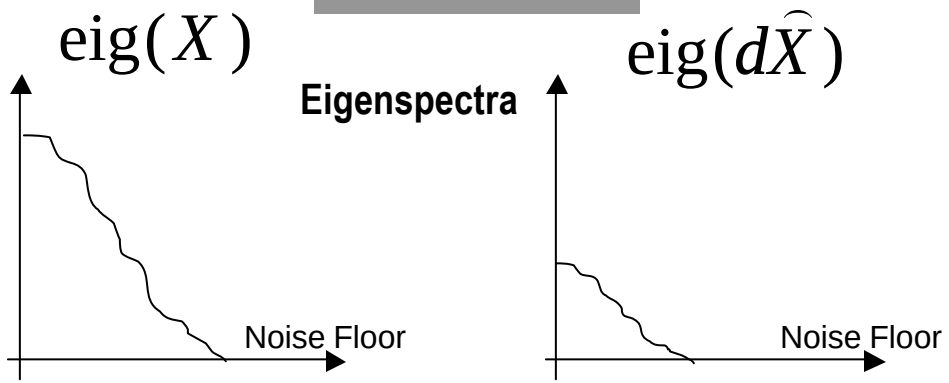




Less bits required for encoding (data compression)

Adaptive DOFs Reduction (Predictive Rank-Reduction)



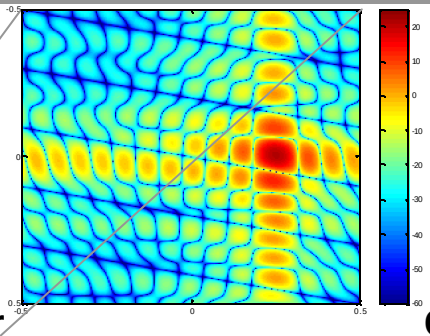


Less adaptive DOFs required for cancellation (rank-reduction)

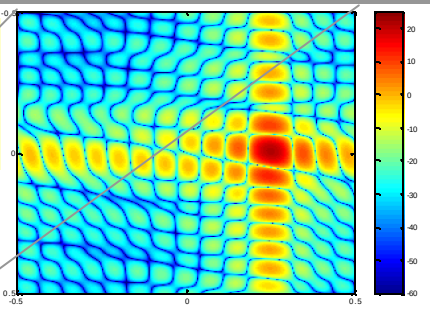
Knowledge-Aided Interference Rejection

Direct use of environmental knowledge base for heterogeneous clutter rejection

1st Stage Knowledge-Aided Pre-Filter Response



2nd Stage Conventional Filter



Nonstationary Clutter (plus Signal)

X

KA Pre-Filter

$R_{KA}^{-\frac{1}{2}}$

$Y = R_{KA}^{-\frac{1}{2}} X$

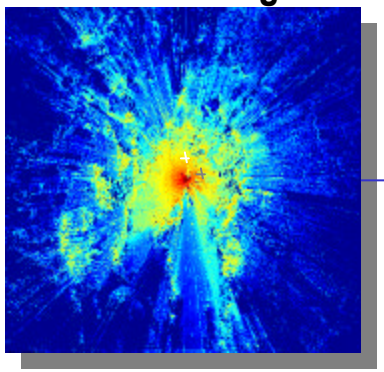
Reduced-Rank Conventional Filter

$\hat{R}_{SMI}^{-\frac{1}{2}}$

$Z = \hat{R}_{SMI}^{-\frac{1}{2}} Y$

Detector

Clutter Knowledge Base



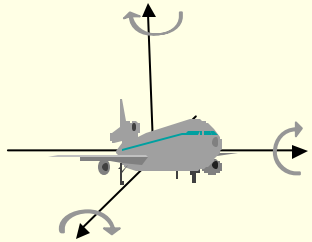
Clutter Cell Returns

$\{g_i\}$

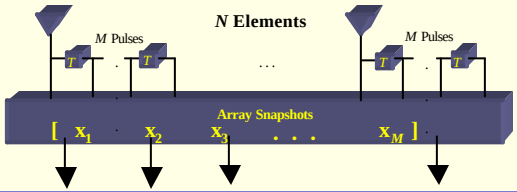
Clutter Steering Vectors

$\{C_i\}$

GPS/INS



Sensor Characteristics

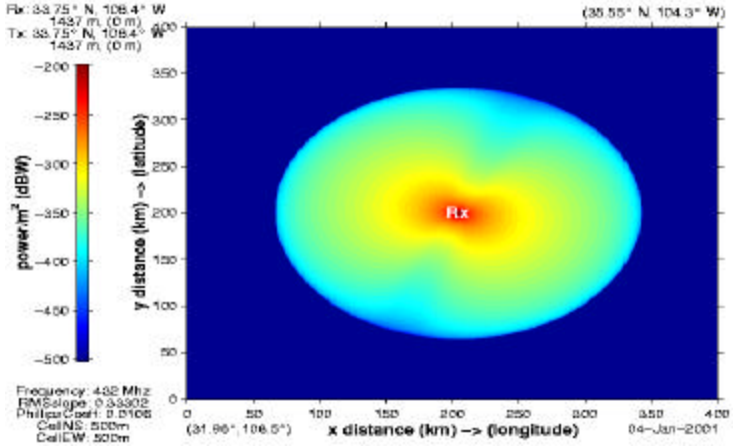


$$R_{KA} = \sum g_i^2 C_i C_i' + s^2 I$$

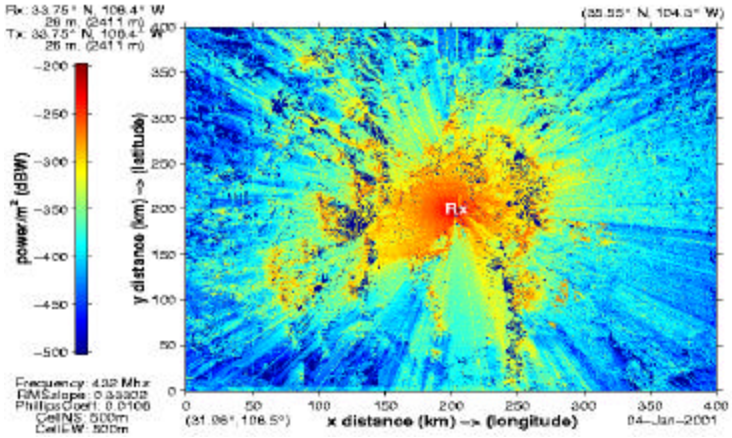
Sum Over Clutter Cells

Existing High Fidelity Clutter Modeling

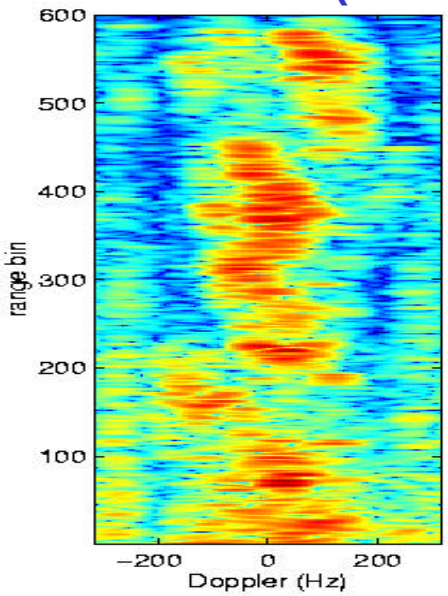
Bald Earth



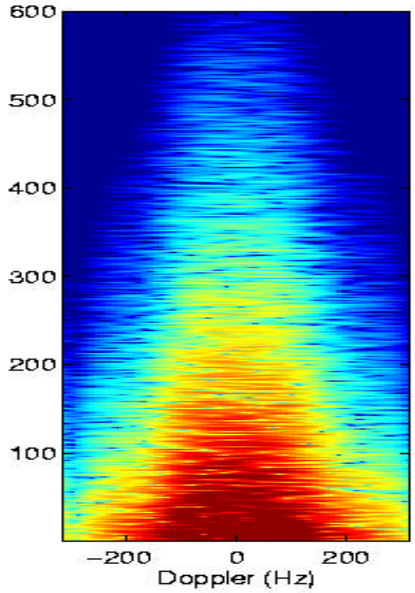
Clutter Model (DTED Level-1)



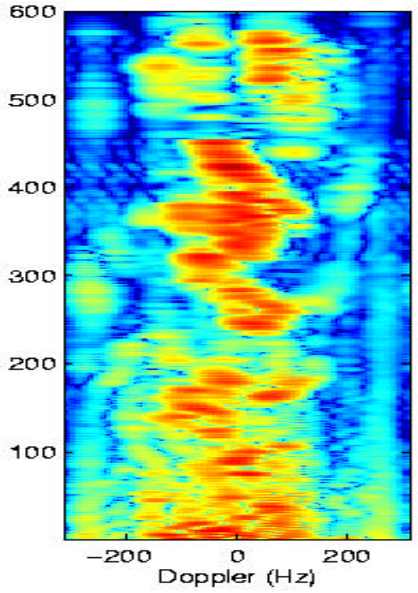
Measured Data (WSMR)



Bald Earth



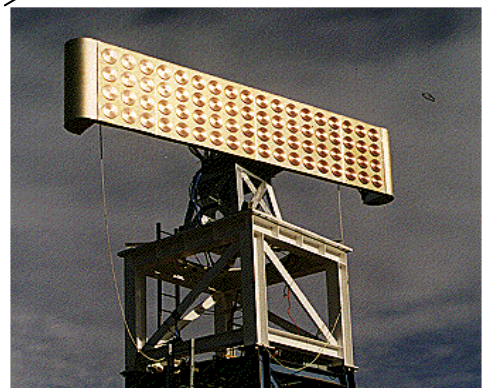
Clutter Model (DTED Level-1)



DARPA MOUNTAIN TOP Performance Significantly Improved Using KASSPER

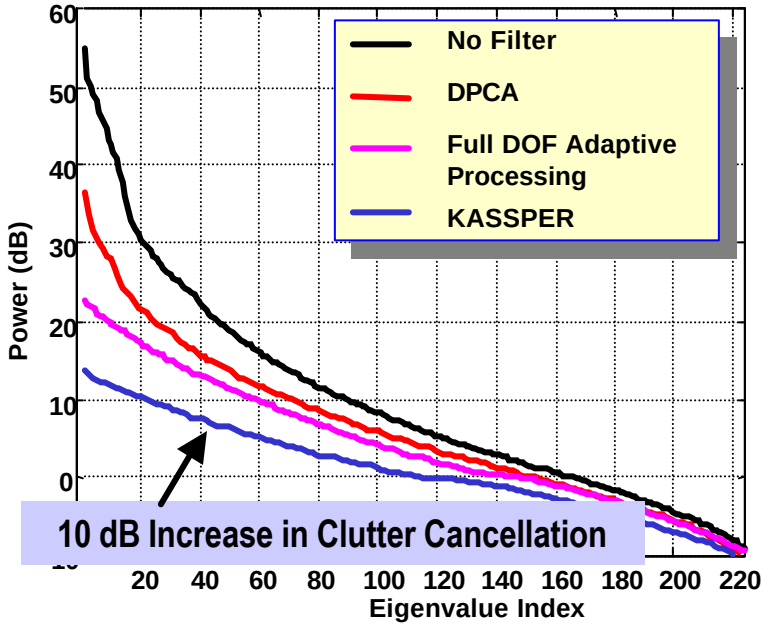
RSTER Radar

IDPCA

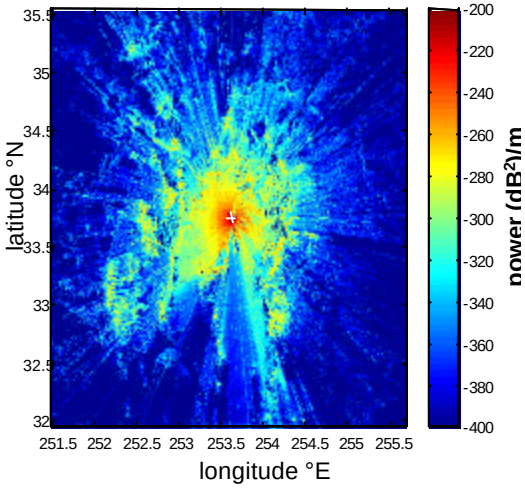


Parameter	Value	Units
Antenna Gain	29	dBi
Transmit Power Peak/Average	100/6	kW
PRF	250-1500	Hz
Operating Frequency	400-500	MHz
Bandwidth	200	kHz
Beamwidth (Azimuth/Elevation)	6/9	degrees

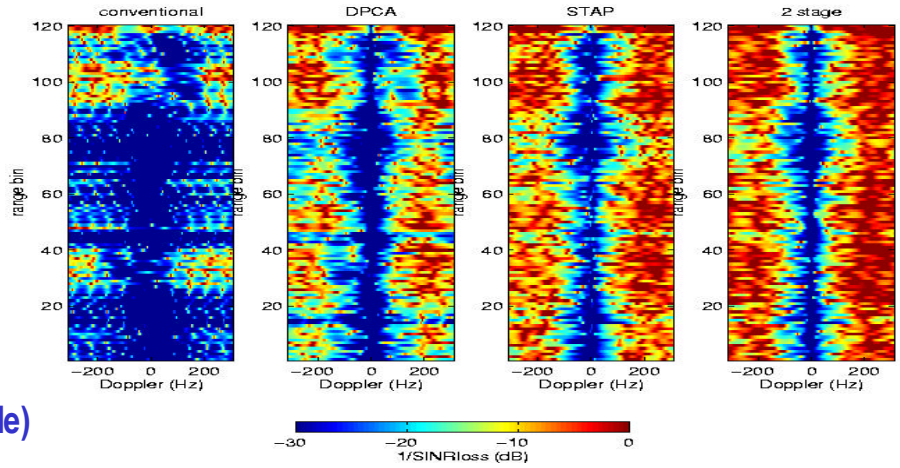
Clutter Cancellation Performance



DTED/DFAD Based Clutter Map



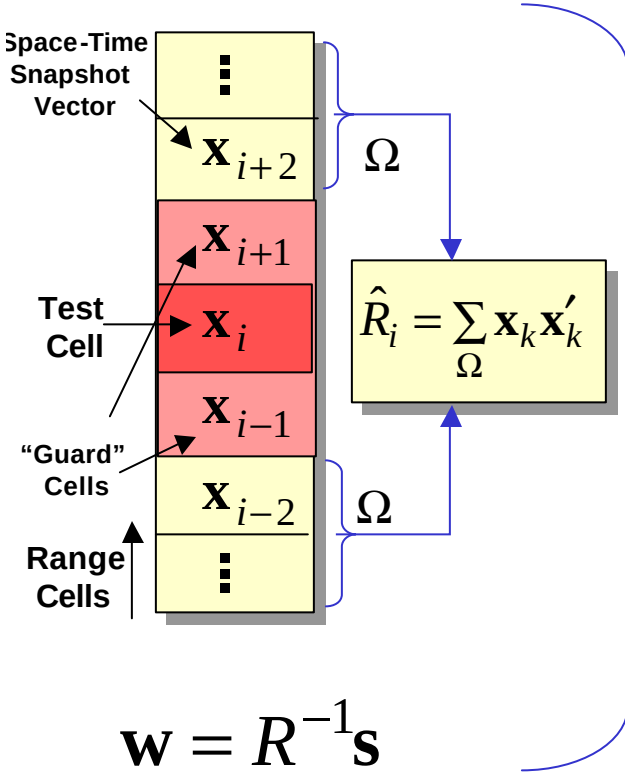
Improved SINR Performance



* Intelligent Training NOT Employed (Further Improvement Possible)

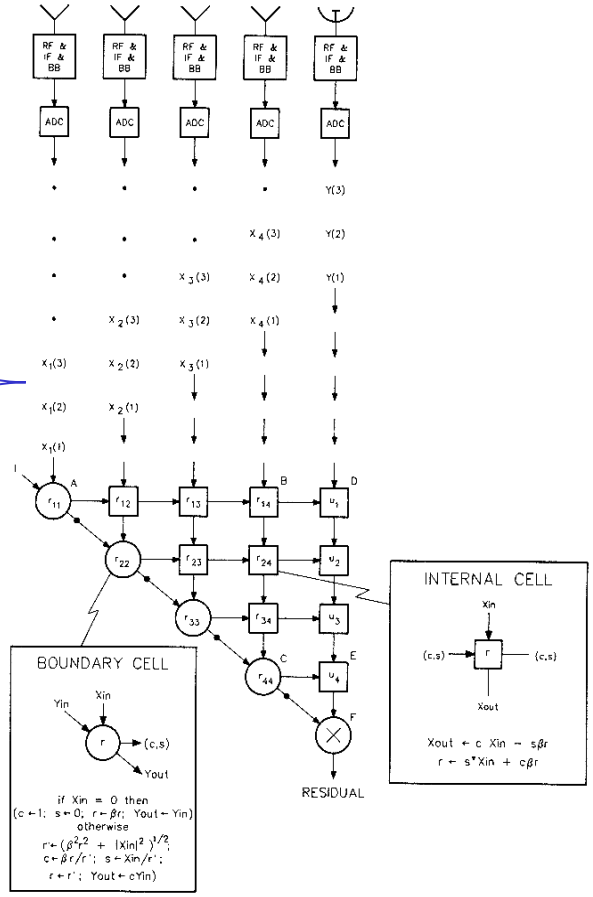
Conventional vs. KASSPER HPEC Processing

Conventional Space-Time Filtering



$$\mathbf{w} = R^{-1}\mathbf{s}$$

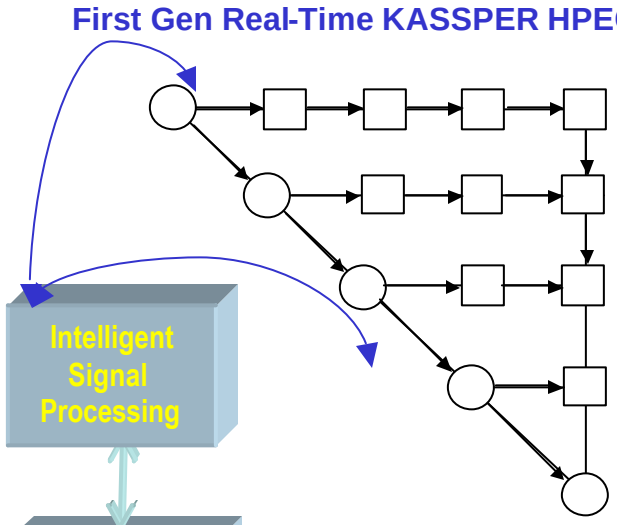
Highly Parallel Systolic Array Implementation (Achieves 100's to 1000's of GFLOPS)



QR Factorization w/ Back substitution

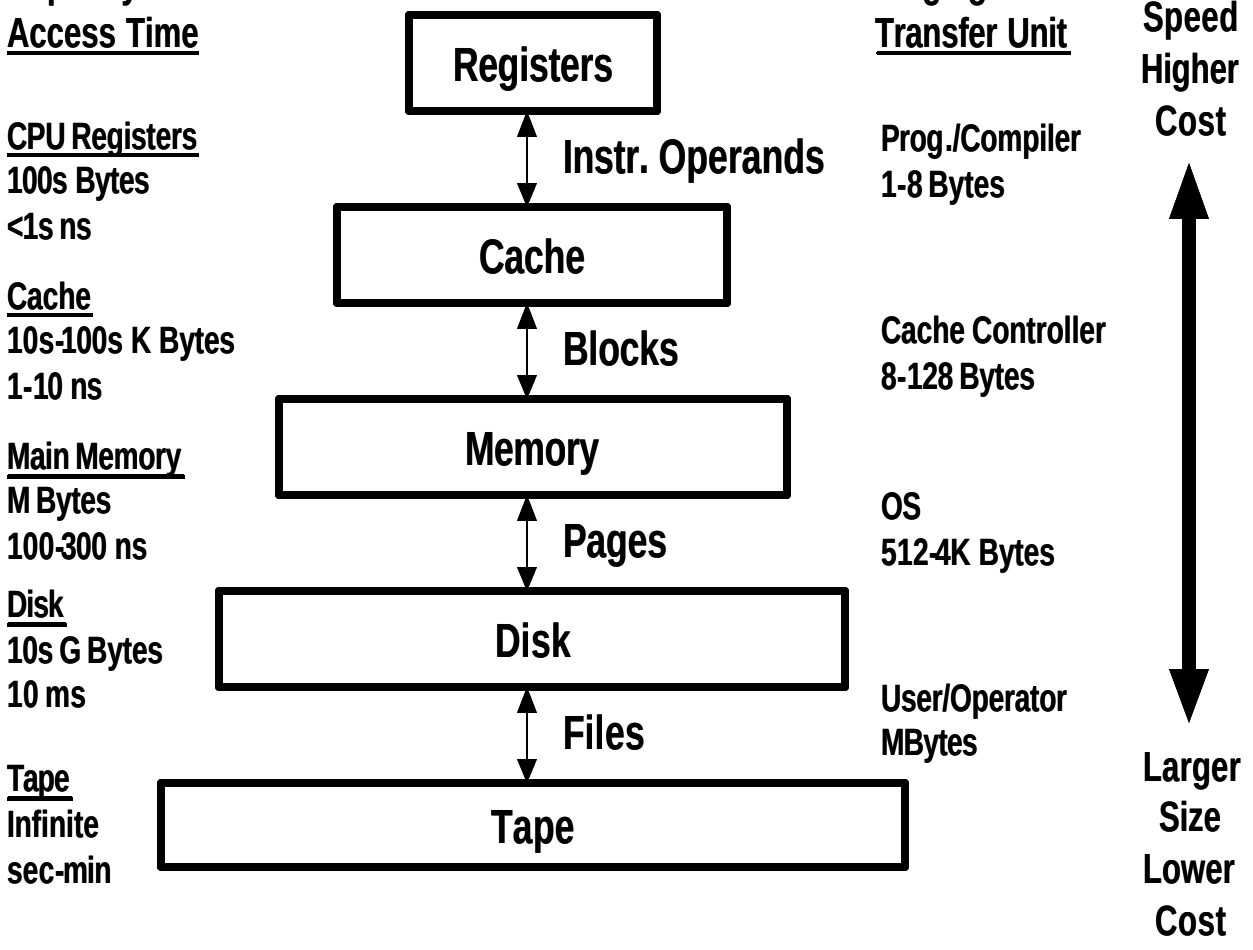
KASSPER HPEC Challenge: Optimizing adaptation by injecting environmental knowledge "intelligently" into the front-end signal flow

First Gen Real-Time KASSPER HPEC



- KASSPER requires memory access interrupts
- Optimal interrupt scheduling
- Optimized ISP
- "Look-Ahead" scheduling

Complex Memory Hierarchy



Source: Dave Patterson, Graduate Computer Architecture Course, University of California, Berkeley, Spring, 2001

Optimized KASSPER "Look-Ahead" Interrupt Scheduling